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Aviation System Analysis Capability Air Carrier Investment Model—Cargo

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The purpose of the Aviation System Analysis Capability (ASAC) Air Cargo Investment Model-Cargo (ACIMC), is to examine the economic effects of technology investment on the air cargo market, particularly the market for new cargo aircraft. To do so, we have built an econometrically based model designed to operate like the ACIM.

Two main drivers account for virtually all of the cargo demand: the growth rate of the Gross Domestic Product (GDP) and changes in the fare yield (which is a proxy of the price charged or fare). These differences arise from a combination of the nature of air cargo demand and the peculiarities of the air cargo market.

The net effect of these two factors are that sales of new cargo aircraft are much less sensitive to either increases in GDP or changes in the costs of labor, capital, fuel, materials, and energy associated with the production of new cargo aircraft than the sales of new passenger aircraft. This in conjunction with the relatively small size of the cargo aircraft market means technology improvements to the cargo aircraft will do relatively very little to spur increased sales of new cargo aircraft.

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Aviation System Analysis Capability Air Carrier Investment Model—Cargo

SUMMARY

The purpose of the Aviation System Analysis Capability (ASAC) Air Cargo Investment Model-Cargo (ACIMC), like that of the original ASAC ACIM, is to examine the economic effects of technology investment on the air cargo market, particularly the market for new cargo aircraft. To do so, we have built an econometrically based model, drawn in part from our previous cargo study (Reference [2]) and designed to operate like the ACIM.

The ACIMC completes the ASAC economic suite of models at the major carrier level. Global-level economic analyses of both cargo and passenger operations of the world's major air carriers is now possible.

The air cargo market shares more differences with the air passenger market than similarities. First and foremost are the demand drivers. The passenger market has a set of complex and interrelated drivers that characterize the demand for air travel. The key point is that air travel demand is the product of a highly competitive process that accounts for both a carrier's fare, as well as those of competitors, and the size and the economic prosperity of the origin and destination cities. This complex structure provides a rich framework for the analysis of the component demand drivers. The component demand drivers can then be broken down into specific elements. These specific elements, such as labor, capital, fuel, materials, and energy costs, can then be linked to specific changes in technology.

This is not the case for the demand for air cargo. Two main drivers account for virtually all of the demand: the growth rate of the Gross Domestic Product (GDP) and changes in the fare yield (which is a proxy of the price charged or fare). These differences arise from a combination of the nature of air cargo demand and the peculiarities of the air cargo market.

The demand for air cargo is a derived demand. It is specifically related to the locational demand for goods produced or manufactured elsewhere. This derived demand is driven primarily by changes in the GDP, the value of currently purchased goods and services by consumers, governments; and driven secondarily by changes in the fare yield. Therefore, the demand for air cargo is not primarily affected by the same factors or the same degree that air passenger demand is. This means that the traditional analysis factors of changes in the costs of labor, capital, fuel, materials, and energy first must be translated to changes in GDP, if appropriate.

Air cargo capacity comes in two forms, belly-cargo in passenger aircraft and cargo-only aircraft. This structure is another reason for the weak link between the traditional analysis factors and the demand for air cargo. The belly-cargo capacity is a by-product of passenger capacity. It represents a secondary revenue stream for the carriers and serves to meet air cargo demand in the markets parallel to passenger demand. This portion of the air cargo capacity is affected by the factors that influence the use of passenger aircraft to meet passenger demand, but not specifically cargo demand. Passenger aircraft outnumber cargo aircraft by a ratio of 15 to 2 in the commercial fleets of the world. This means that a major portion of air cargo capacity is being added not out of a response to air cargo demand, but to passenger demand.

Cargo-only aircraft are disproportionally converted-used passenger aircraft versus purchased-new cargo aircraft. In the U.S. major commercial cargo aircraft fleet, the historical ratio of purchased used to purchased new is slightly higher than 8 to 3. For the decade of the 90s this ratio has increased to 7 to 2. This is part of the dynamics of the air cargo market: large lift capacity is available as a by-product of passenger demand and the costs of new cargo-only aircraft are beyond the financial reach of all but the most financially secure carriers.

The net effect of these two factors are that sales of new cargo aircraft are much less sensitive to either increases in GDP or changes in the costs of labor, capital, fuel, materials, and energy associated with the production of new cargo aircraft than the sales of new passenger aircraft. This in conjunction with the relatively small size of the cargo aircraft market means technology improvements to the cargo aircraft will do relatively very little to spur increased sales of new cargo aircraft.

INTRODUCTION AND OVERVIEW

This report develops and presents a model developed by the Logistics Management Institute (LMI) for analyzing the economic effects of technology investment on the air cargo market. In particular, the major result is the number of new additional sales of cargo aircraft garnered from technology investment. The model, the ACIMC, is econometrically based and drawn in part from previous cargo work (NASA/CR-1998-207655) and designed to operate like the ACIM.

Background

The present work continues efforts at the Logistic Management Institute (LMI) under NASA's initiative to assess technology research projects with estimates of their economic effects. Earlier efforts led to NASA's developing the ASAC, which provides on-line data and analytical resources for analyzing economic impacts of technologies for air transportation. ASAC's databases include air carrier operating costs, airport operations, air travel forecasts, aircraft inventories, deliveries, and demand. They are integrated with aircraft design models and economic models. ASAC provides convenient access to the integrated suite of data and models via the World Wide Web (WWW).

Here, we extend the ASAC analysis capability to include global-level economic analysis of the effect of technology investment on the market for new cargo aircraft.

Objectives

The study's principal objectives are

- to develop an analytical model of the ASAC ACIMC that calculates future fleet requirements and the fleet mix by new or used aircraft; and
- to provide estimates of the benefits of technology investment in air cargo aircraft, in terms of new cargo aircraft sales and the resulting airline and manufacturing employment.

Approach

We developed an econometrically based model using the results of the previous cargo study as the starting point. An algorithm that estimates future revenue ton miles (RTMs) for both the domestic and international cases was developed first. The RTMs then were split into those flown on passenger aircraft and those flown on all-cargo aircraft. Next, the yearly additional all-cargo aircraft carried RTMs was then translated into a yearly additional all-cargo aircraft requirement. Subsequently, the additional all-cargo aircraft requirement was then divided into those purchased as new and those purchased as used. The purchased new all-cargo aircraft was further divided into those domestically purchased versus foreign purchased. For those domestically purchased-new all-cargo aircraft, the benefits, in terms of manufacturing and airline employment, were then calculated.

The continuing analysis paradigm is one of comparative analysis. A baseline case is analyzed first. A case representing changes or technology injection is then analyzed. The difference between the two cases represents the benefits due to that particular change or technology injection/investment.

Description of This Report

This report presents the results of the study outlined above. First, the analytical construction of the model developed is addressed. A range of test cases used to verify the model are analyzed next. Appendix A is a user's manual and Appendix B lists the abbreviations used throughout the document.

MODEL CONSTRUCTION

In this section, we analyze development of the ACIMC. We start with the historical analysis of RTM to produce an econometric-based estimate of RTM growth over the next 20 years. The RTM estimates then are split into RTMs carried by passenger aircraft and RTMs carried by all-cargo aircraft. The estimate of RTMs carried by all-cargo aircraft drives the cargo fleet size estimates. The cargo fleet size then is decomposed into yearly additions to the cargo fleet. For each year, the number of new cargo aircraft purchased is calculated. This number is then split into U.S. and foreign purchases. The economic effects of the U.S.-purchased new cargo aircraft are then evaluated. This includes manufacturing work years and total manufacturing value as well as the resultant aviation industry employment.

Revenue Ton Miles Estimation

The model starts with an estimate of the future RTM growth. This portion of the model was developed by Dr. Eric Gaier of LMI as part of the previous cargo study [2]. The data were updated, and the same methodology was used for this study. The rest of this section is updated from Reference [2].

The first step was to collect historical data regarding cargo traffic, freight yield, and income for each of the two regions over the 18-year period 1980 to 1997. In order to capture both the volume and the distance components of cargo shipments, we selected RTMs—or alternatively revenue tonne kilometers (RTKs) for the World region—as the measure of cargo traffic. The World cargo RTKs are derived from ICAO-published traffic statistics and include both scheduled and non-scheduled revenue traffic. Similarly, we aggregated U.S. cargo RTMs from individual carrier's Form 41[1] reports and included both scheduled and non-scheduled traffic.

We used the average yield for scheduled freight (measured in constant U.S. dollars per RTK) as our measure of fare yield for the World region.[2] Similarly, we used the average yield (measured in constant U.S. dollars per RTM) as our measure of fare yield for the U.S. region.[3] In addition, for the U.S. region, we made a distinction between observations preceding the initiation of express service with regard to real yield. The rationale is to allow for the possibility that the relationship between yield and traffic volume was altered by the introduction of express service.

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[1] Form 41 data is the federally mandated and publicly available collection of operational and financial data which describes the operations and status of individual carriers and when taken in aggregate, the domestic air carrier industry as a whole. It consists of financial and traffic data specifically composed of a series of monthly, quarterly, and annual reports.

[2] World average scheduled freight yield statistics are published in *Civil Aviation Statistics of the World* by ICAO.

[3] U.S. average freight yield was explicitly calculated from the Form 41 revenue and traffic series.

To measure world income, we used the total gross domestic product (GDP) (measured in constant U.S. Dollars) of the 29 members of the Organization of Economic Cooperation and Development (OECD). These nations comprise the largest market economies in the world and account for the vast majority of international trade. Finally, we used real GDP to measure income for the U.S. region.

Next we constructed an econometric model of cargo demand for each region. Formally the models for the World and U.S. regions are represented, respectively, by

$$q_t^W = D_t^W(y_t^W, p_t^W) \text{ and} \qquad \text{[Eq. 1]}$$

$$q_t^{US} = D_t^{US}(y_t^{US}, p_t^{US}, x_t^{US}), \qquad \text{[Eq. 2]}$$

where q_t^i is cargo traffic in region *i* at time *t*, y_t^i is real income in region *i* at time *t*, p_t^i is real yield in region *i* at time *t*, and x_t^{US} is real yield after the initiation of express service in the United States at time *t*. To correct for the possibility of serial correlation in the data, we employed an autoregressive model with two lags of the error terms. We used a log-log specification so that the coefficients may be interpreted as elasticities. The overall fit of the econometric models is quite good with coefficients of determination (adjusted R-square) of 0.9878 and 0.9793 for the World and U.S. regions, respectively. The econometric results are presented in Table 1.

Table 1. Demand Variables

Region	Variable	Name	Coefficient	T-ratio
World	Real income	LNGDP	2.3925	11.97
	Real yield	LNYIELD	-0.0761	-0.43
U.S.	Real income	LNGDP	2.3639	5.22
	Real yield	LNYIELD	-0.3662	-1.13
	Real yield (express)	LNXPRESS	-0.2582	-2.24

From the econometric results, we constructed an analytic model to forecast changes in cargo demand for each of the two regions. To predict demand, the model starts with actual cargo traffic for calendar year 1997 and changes it over time based on the estimated demand function coefficients and assumptions regarding explanatory variables. The equation for predicting annual changes in demand is

$$\%\Delta RTM = \sum_{i=1}^{3} \beta_i \, \%\Delta X_i , \qquad \text{[Eq. 3]}$$

where the β_i are the coefficients estimated from the econometric model, and the X_i are the explanatory variables. Due to the logarithmic structure of the statistical model, the coefficients are interpreted as elasticities. For example, the coefficient of 2.3925 on world income means that a 1 percent increase in GDP raises the demand for air cargo by 2.3925 percent.

The baseline assumptions regarding changes in real income and real fare yield are drawn from assumptions published in *Boeing's World Air Cargo Forecast*. These assumptions are summarized in Table 2.

Table 2. Baseline Assumptions

Region	Variable	Annual growth rate (%)
World	Real income	3.00
	Real yield	-1.00
U.S.	Real income	2.30
	Real yield	-1.00

RTM Estimates

Starting with 1997 traffic totals, and applying the assumptions of Table 2 to the coefficients of Table 1, we generated forecasts of cargo traffic for each region for the 20-year period 1998 through 2017. These data are shown in the second and third columns of Tables 5 and 6 for the U.S. and World regions, respectively.

We project that World cargo RTM traffic will grow at annual rate of 7.25 percent, which is well within the range of 4.5 to 8.1 percent projected by Boeing for the same time period. Furthermore, we project that U.S. flag cargo RTM traffic will grow at an annual rate of 5.8 percent, which is very near the Boeing projection of 5.5 percent growth over the same time period.

For the international analysis, the U.S. data was subsumed in the world data. The methodology is exactly the same as before, with the sole difference being values of the key parameters. Here the worldwide GDP growth rate is set to 3.0 percent, which translates to an annualized RTM growth rate of 7.25 percent.

These two demand projections are the primary determinants of the size of the future cargo fleet. The annual data for both cases is shown in Tables 5 and 6.

RTM Splits

The next step is to split the RTM estimates into those flown on passenger aircraft and those flown on all-cargo aircraft. As before, this is also done by regression analysis. Using a combination of actual and interpolated Form 41 data, the passenger aircraft-cargo aircraft split RTM splits for U.S. carriers is found. The ICAO sources provide similar data at the international level.

Formally, the models for the World and U.S. regions are represented, respectively, by the linear regression equations of

$$y^{W} = m^{W} x^{W} + b^{W} , \qquad \text{[Eq. 4]}$$

$$y^{US} = m^{US} x^{US} + b^{US} , \qquad \text{[Eq. 5]}$$

where y^i is cargo aircraft carried RTMs in region *i*, m^i is the ratio of cargo aircraft carried RTMs to total RTMs in region *i*, x^i is total RTMs in region *i*, and b_t is the constant RTM factor used as the intercept of the linear equation. The overall fit of the econometric models is quite good with coefficients of determination (adjusted R-square) of 0.9981 and 0.9780 for the World and U.S. regions, respectively. The econometric results are presented in Table 3.

Table 3. Demand Variables

Region	Variable	Coefficient	T-ratio
World	slope	0.65	32.91
	intercept	-8900601.00	-8.42
U.S.	slope	0.80	-6.86
	intercept	-5683657.00	20.01

Cargo Fleet Projections

The combination of total RTMs and RTMs carried by cargo aircraft drive the cargo fleet projection, for both the U.S. and World fleets. It is an iterative equation where the cargo fleet in year *t*+1 is a combination of the fleet in year *t* plus a function of the additional total RTMs and the additional RTMs flown by cargo aircraft in year *t*+1.

Formally, the model for the World region is represented by the iterative equation

$$F_{t+1} = F_t + k \ (c^1 (x_{t+1} - x_t) + c^2 (y_{t+1} - y_t)) , \qquad \text{[Eq. 6]}$$

where F_t is the cargo fleet size at time *t*, k is a constant representing the transformation from the change in RTMs flown to the number of cargo aircraft required to meet that change, c^1 is the constant representing the slope of the World total RTMs equation from the demand regression, c^2 is the constant representing the slope of the World total RTMs carried by the cargo aircraft in equation from the RTM split regression, x_t are the World total RTMs at time *t*, and y_t are the cargo aircraft-carried World RTMs at time *t*.

The corresponding model for the U.S. region is represented by the iterative equation

$$F_{t+1} = F_t + (c^1((x_{t+1} - x_t) / 2)) \,, \qquad \text{[Eq. 7]}$$

where F_t is the cargo fleet size at time t, c^1 is the constant representing the slope of the Total RTMs equation from the demand regression, and x_t are the U.S. Total RTMs at time t.

Once the yearly fleet sizes are computed, the number of total cargo aircraft added to the cargo fleet each year is simply the difference between the fleet sizes by year. The cargo fleet projections for the U.S. and World regions are show in the fourth and fifth columns of Tables 5 and 6, respectively.

Purchased New Versus Old Split of Added Cargo Aircraft

The next step is to determine the new versus used split of the cargo aircraft added to the fleet. The current cargo fleet is overwhelmingly composed of converted used passenger aircraft rather than purchased new cargo aircraft. This is largely due to the nature of the cargo market itself. The major passenger carriers can offer large lift capacity by using the belly storage of their passenger aircraft. Therefore, they can easily serve markets where the demand for cargo transport is parallel to the demand for passenger transport. The cost of this large lift capacity is very small because it is a by-product of providing passenger service. The rest of the market is composed of much smaller carriers operating older converted passenger aircraft, with the notable exceptions of Federal Express and the United Parcel Service. This market structure allows a second tier of cargo-carrying airlines to make a profit using those used passenger aircraft. This set of carriers does not have the financial standing to purchase or lease new cargo aircraft. Furthermore, for them, it is highly unlikely that the pricing structure would produce enough cash flow to make the large payments tied to ownership of a new cargo-only aircraft.

During the recent economic upswing, new cargo aircraft have accounted for about 30 percent of the cargo fleet additions. The increases in both passenger and cargo demands is not expected to produce an upward shift in that percentage for two main reasons. First, the increase in passenger traffic generates additional lift capacity to the current passenger markets along with the new passenger markets that have arisen due to passenger demand growth. Therefore, the cargo growth occurring outside of the passenger markets will continue to be met by those traditional sources, the cargo airlines operating used aircraft. Furthermore, the Noise Law will prematurely retire many Stage 2 aircraft. This forced retirement will temporarily lower the cost of those aircraft. The oldest of those passenger aircraft will be available for cargo conversion, further limiting the possibility of any higher than usual new cargo aircraft sales.

Using the 30 percent split value, the yearly projections of the number of new cargo aircraft added to the fleet for both the U.S. and World regions are shown in the last column of Tables 5 and 6, respectively. This value has been set as a parameter that also can changed on a yearly basis.

New Domestic Versus Foreign Market Shares

The market share data are drawn from a market share study of the commercial aircraft industry performed by Dr. Abel Fernandez, under contract to LMI. His study examined over 22 regression models to determine the best type of analysis for accurate market share prediction. The yearly market shares were developed using Monte Carlo simulation-based forecasting techniques and a set of linear regression models. The predictor variables in the regression equations were modeled as random variables within a spreadsheet simulation model. The probability distribution functions of the predictor variables are determined from the historical data. The regression predictions are exponentially smoothed to highlight the long-term trends over the 20-year forecast horizon. The market share of new U.S. region cargo aircraft starts at 69 percent in 1997 and ends at 75 percent in 2017. The market share of the World region starts at 65 percent and ends at 69 percent over the same time interval. The yearly U.S. market shares and their resultant new cargo aircraft sales for both the U.S. and World regions are shown in the second and third columns of Tables 7 and 8, respectively.

Industry Effects

The final analysis step is to calculate the economic effects of the purchases of new U.S. manufactured cargo aircraft. There are three effects of interest: (1) manufacturing work years, (2) manufacturing value, and (3) air carrier industry employment.

Manufacturing work years are defined as employment years per $1 million of aircraft sales. Manufacturing value is defined as the sum of the value of all the goods and services used to produce $1,000,000 of aircraft sales. Air carrier industry employment is the total number of employees added to fly, service, and maintain an aircraft newly added to the fleet.

The initial parameter values were determined by Mr. Earl Wingrove using a Leontief-based Input-Output analysis. These parameters were first used as part of Reference [3], but are implemented in this study as changeable scenario variables. The cost of a new cargo aircraft is based on the cost of a new cargo aircraft weighted by the type of number of those size aircraft already in the fleet. The value of these four parameters is shown in Table 4.

Once the number of new U.S.-made cargo aircraft is known, the calculation of the resulting work years, manufacturing value, and air carrier industry employment is fairly straightforward. The yearly values are shown in the last 3 columns of Tables 7 and 8.

Table 4. Industry Effect Economic Parameters

Parameter	Value
Manufacturing work years per $1,000,000 of aircraft sales	5.78
Manufacturing value per $1,000,000 of aircraft sales	$2,128,950
Air carrier industry employees per aircraft	120
Weighted cost of a new cargo aircraft	$106,830,000

Table 5. U.S. Baseline Fleet Estimates for 1997–2017

Year	U.S. flag RTMs (billions)	U.S. flag cargo aircraft-carried RTMs (billions)	Cargo fleet size	Yearly cargo aircraft added	New cargo aircraft added
1997	26.70	16.12	987.0	52.0	15.6
1998	28.25	16.32	1,010.0	23.0	6.9
1999	29.89	16.80	1,034.3	24.3	7.3
2000	31.62	17.50	1,060.1	25.7	7.7
2001	33.46	18.40	1,087.3	27.2	8.2
2002	35.40	19.46	1,116.1	28.8	8.6
2003	37.45	20.66	1,146.6	30.5	9.1
2004	39.63	22.00	1,178.9	32.3	9.7
2005	41.93	23.47	1,213.0	34.1	10.2
2006	44.36	25.05	1,249.1	36.1	10.8
2007	46.93	26.75	1,287.3	38.2	11.5
2008	49.66	28.58	1,327.8	40.4	12.1
2009	52.54	30.52	1,370.5	42.8	12.8
2010	55.59	32.59	1,415.8	45.3	13.6
2011	58.81	34.78	1,463.7	47.9	14.4
2012	62.23	37.11	1,514.3	50.7	15.2
2013	65.84	39.58	1,567.9	53.6	16.1
2014	69.66	42.20	1,624.6	56.7	17.0
2015	73.70	44.97	1,684.6	60.0	18.0
2016	77.98	47.90	1,748.1	63.5	19.0
2017	82.50	51.00	1,815.3	67.2	20.1
Summary	5.80%	5.94%	3.09%	880	264

Table 6. World Baseline Fleet Estimates for 1997–2017

Year	World flag RTMs (billions)	World flag cargo aircraft-carried RTMs (billions)	Cargo fleet size	Yearly cargo aircraft added	New cargo aircraft added
1997	73.63	38.96	1,476.0	81.0	24.3
1998	78.97	42.43	1,526.0	50.0	15.0
1999	84.70	46.15	1,576.8	50.7	15.2
2000	90.84	50.15	1,628.1	51.4	15.4
2001	97.43	54.43	1,680.1	51.9	15.6
2002	104.50	59.02	1,732.6	52.5	15.7
2003	112.08	63.95	1,785.5	52.9	15.9
2004	120.21	69.24	1,838.9	53.4	16.0
2005	128.93	74.90	1,892.7	53.8	16.1
2006	138.28	80.98	1,946.8	54.1	16.2
2007	148.31	87.50	2,001.3	54.5	16.3
2008	159.07	94.49	2,056.1	54.8	16.4
2009	170.61	101.99	2,111.2	55.1	16.5
2010	182.98	110.04	2,166.5	55.3	16.6
2011	196.26	118.67	2,222.1	55.6	16.7
2012	210.49	127.92	2,277.9	55.8	16.7
2013	225.76	137.84	2,333.9	56.0	16.8
2014	242.14	148.49	2,390.1	56.2	16.9
2015	259.70	159.90	2,446.5	56.4	16.9
2016	278.54	172.15	2,503.0	56.5	17.0
2017	298.74	185.28	2,559.7	56.7	17.0
Summary	7.25%	8.11%	2.79%	1164.7	349.4

Table 7. U.S. Baseline Industry Effects Estimates for 1997-2017

Year	Domestic market share (%)	New cargo air-craft made in the U.S.	Resultant manufacturing work years	Resultant manufacturing value ($ millions)	Resultant air carrier industry employment (people)
1997	69	10.8	6,647	2,448	1,292
1998	70	4.8	2,982	1,098	580
1999	70	5.1	3,155	1,162	613
2000	70	5.4	3,338	1,230	649
2001	71	5.8	3,582	1,320	696
2002	71	6.1	3,790	1,396	737
2003	72	6.6	4,067	1,498	790
2004	72	7.0	4,303	1,585	836
2005	72	7.4	4,552	1,677	885
2006	73	7.9	4,883	1,799	949
2007	73	8.4	5,167	1,903	1,004
2008	73	8.9	5,467	2,014	1,062
2009	74	9.5	5,863	2,160	1,139
2010	74	10.0	6,203	2,285	1,206
2011	74	10.6	6,563	2,418	1,276
2012	75	11.4	7,038	2,592	1,368
2013	75	12.1	7,447	2,743	1,447
2014	75	12.8	7,879	2,902	1,531
2015	75	13.5	8,336	3,070	1,620
2016	75	14.3	8,820	3,249	1,714
2017	75	15.1	9,331	3,437	1,813
Summary		192.5	119,414	43,984	23,207

Table 8. World Baseline Industry Effects Estimates for 1997–2017

Year	Domestic market share (%)	New cargo aircraft made in the U.S.	Resultant manufacturing work years	Resultant manufacturing value ($ millions)	Resultant air carrier industry employment (people)
1997	65	15.8	9,753	3,592	1,895
1998	65	9.8	6,025	2,219	1,171
1999	65	9.9	6,109	2,250	1,187
2000	65	10.0	6,185	2,278	1,202
2001	65	10.1	6,255	2,304	1,216
2002	66	10.4	6,415	2,363	1,247
2003	66	10.5	6,473	2,384	1,258
2004	66	10.6	6,527	2,404	1,268
2005	67	10.8	6,675	2,459	1,297
2006	67	10.9	6,721	2,475	1,306
2007	67	11.0	6,762	2,491	1,314
2008	67	11.0	6,800	2,505	1,322
2009	68	11.2	6,938	2,555	1,348
2010	68	11.3	6,971	2,567	1,355
2011	68	11.3	7,001	2,579	1,361
2012	68	11.4	7,029	2,589	1,366
2013	68	11.4	7,055	2,598	1,371
2014	69	11.6	7,183	2,646	1,396
2015	69	11.7	7,205	2,654	1,400
2016	69	11.7	7,226	2,661	1,404
2017	69	11.7	7,245	2,668	1,408
Summary		234.1	144,551	53,242	28,092

ANALYSIS OF TEST CASES

The ASAC ACIM has been tested under three different scenarios: Technologies A, B, and C. Technology A brings a reduction in the weight of the aircraft, which will reduce block fuel usage. This serves to lower fuel costs of the aircraft, although the actual price of the aircraft may rise due to the use of advanced composites. Technology B brings propulsion improvements, which reduce block fuel. This technology also lowers fuel costs but with a definite increase in the price of the aircraft/engine combination. Technology C reduces block time, which serves to increase capital productivity. Depending upon who pays and how that payment is extracted, such airspace or airport space improvements may or may not increase or decrease the operating costs of the aircraft.

In any case, these specific technology improvements are targeted at passenger aircraft, not cargo aircraft. There is no doubt that any improvements in technology will ultimately reach the cargo aircraft, although the effect is likely to be both delayed and muted. It will be delayed in that any new technology will first be applied and sold as benefiting the passenger demand, not the cargo demand. Cargo is not sensitive to noise, speed, or any number of customer-specific service improvements. The effects will be delayed until the technology is pervasive and becomes a part of standard production. These effects also will be muted because the sales of new cargo aircraft are small relative to those of passenger aircraft.

Methodology

The key drivers of cargo RTMs are the changes in GDP and cargo yield. A set of test cases were developed to examine the effects of various economic scenarios on U.S. sales of cargo aircraft. These scenarios are defined in terms of changes in economic growth (GDP growth) and level of competition in the cargo industry (cargo yield). The two drivers are divided into three levels: high, average, and low. The values of the parameters are shown in Table 9. The high set of values represent the maximum values that the parameters can assume. Similarly, the low set of values represent the minimum values that the parameters can assume. The average set of values represent the average long-term estimate for each of the parameters.

Table 9. Gross National Product and Cargo Yield Test Parameters

Level	World GDP growth (%)	U.S. GDP growth (%)	World cargo yield (%)	U.S. cargo yield (%)
High	5.0	3.0	-2.5	-2.5
Average	3.0	2.3	-1.0	-1.0
Low	2.0	1.6	0.5	0.5

A total of nine test cases were examined. They were composed by varying the two sets of drivers, GDP and cargo yield, through the low, average and high values. The values of each test case are show in Table 10.

Table 10. Summary of the Test Cases

Test case number	Name/characterization (GDP growth, cargo yield)	World GDP growth (%)	U.S. GDP growth (%)	World cargo yield (%)	U.S. cargo yield (%)
1	(High, High)	5.0	3.0	-2.5	-2.5
2	(High, Average)	5.0	3.0	-1.0	-1.0
3	(High, Low)	5.0	3.0	0.5	0.5
4	(Average, High)	3.0	2.3	-2.5	-2.5
5	(Average, Average)	3.0	2.3	-1.0	-1.0
6	(Average, Low)	3.0	2.3	0.5	0.5
7	(Low, High)	2.0	1.6	-2.5	-2.5
8	(Low, Average)	2.0	1.6	-1.0	-1.0
9	(Low, Low)	2.0	1.6	0.5	0.5

Analysis

The nine test cases were run and the results are shown in Tables 11 and 12. The results are stated in terms of differences from the baseline case. Case 5, which is average GDP growth and average cargo yields, is the baseline case.

Table 11. U.S. Model—Summary Results of Economic Effects

Year	Change in new cargo aircraft made in the U.S. (per year)	Change in manufacturing work years	Change in manufacturing value ($ millions)	Change in air carrier industry employment (people)
Case 1	138.58	85,571	31,518	16,630
Case 2	98.79	60,998	22,467	11,854
Case 3	62.70	38,713	14,259	7,523
Case 4	29.60	18,274	6,731	3,551
Case 5	0	0	0	0
Case 6	-26.79	-16,545	-6,094	-3,215
Case 7	-51.33	-31,694	-11,674	-6,159
Case 8	-72.23	-45,216	-16,655	-8,787
Case 9	-93.02	-57,438	-21,156	-11,162

Table 12. World Model—Summary Results of Economic Effects

Year	Change in new cargo aircraft made in the U.S. (per year)	Change in manufacturing work years	Change in manufacturing value ($ millions)	Change in air carrier industry employment (people))
Case 1	147.55	91,109	33,558	17,706
Case 2	144.16	89,015	32,787	17,299
Case 3	140.76	86,919	32,015	16,892
Case 4	3.48	2,146	790	417
Case 5	0	0	0	0
Case 6	-3.48	-2,146	-790	-417
Case 7	-69.50	-42,917	-15,808	-8,340
Case 8	-72.99	-45,068	-16,600	-8,758
Case 9	-76.47	-47,218	-17,392	-9,176

Cases 1 and 9 also deserve special mention because they represent the upper and lower limits of the scenario values—the best and worst results that can be achieved. Case 1 shows that under the best economic conditions, the United States can expect to sell 6.5 to 7 additional new cargo aircraft per year over the next 20 years. Conversely, under the worst economic conditions (Case 9), the United States can expect to sell approximately 4 to 5 new cargo aircraft. Considering that the new U.S.-built cargo aircraft sales volume averages 58 per year over the next 20 years for the world, neither of these limits are that extreme.

These data also indicate that the changes in the GDP have a greater effect on new cargo aircraft sales than do changes in the cargo yield. This is to be expected because the demand for cargo (which indirectly is the demand for new cargo aircraft) is affected more by general economic growth than it is by the prices that shippers charge.

References

[1] Abel Fernandez, *Market Share Study: Commercial Aircraft Industry, Phase III - U.S. Market Share Predictor Models and Forecast Through the Year 2016*, Old Dominion University, Norfolk, VA, August 1997.

[2] Jesse Johnson and Eric Gaier, *Air Cargo Operations Cost Database,* NASA/CR-1998-207655, NASA Langley Research Center, Hampton, VA, April 1998.

[3] Earl Wingrove, Eric Gaier and Tara Santmire, *The ASAC Air Carrier Investment Model (Third Generation),* NASA/CR1988-207656, NASA Langley Research Center, Hampton, VA, February 1998.

[4] *World Jet Inventory at Year End 1997,* Jet Information Services, Inc., Woodinville, WA, 1998.

Appendix A
User's Guide

This appendix contains two sections. The first describes how to operate the model; the second details how to update it.

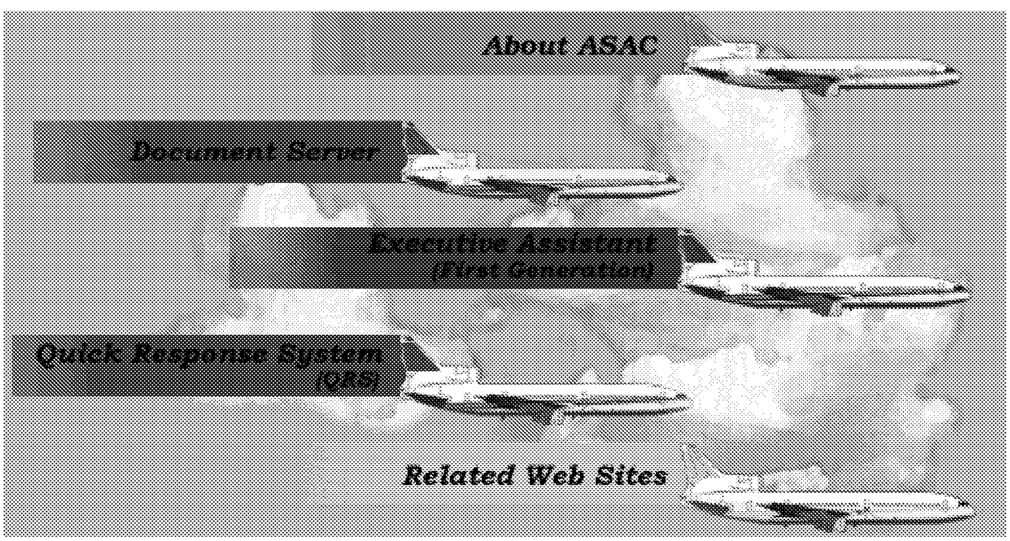
MODEL OPERATION

The ACIMC model is implemented as part of the ASAC suite. It is composed of two pieces, the ACIMC and the Air Cargo Utility. The ACIMC actually runs the model under user-defined scenarios while the Air Cargo Utility compares two sets of scenario results from the ACIMC.

ASAC ACIMC

The ACIMC is part of the ASAC system. The ASAC system is accessed via the World Wide Web at WWW.ASAC.LMI.ORG.

Figure A-1. Opening Screen



Once on the front page of the Web site (Figure A-1), the ASAC suite of models are accessed as follows:

- Click on the **Quick Response System (QRS)** option.
- Click on the **Enter ASAC Quick Response System** option.

- Type in your ASAC ID and ASAC password.

  Note: If you do not have a password, click on the **Become a member of ASAC** link and follow the on screen directions.

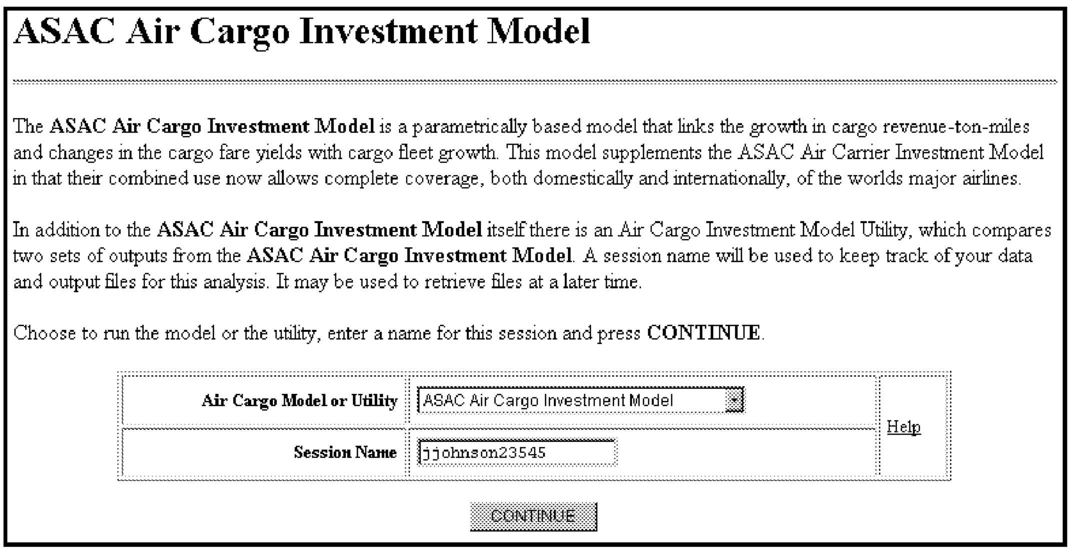
- Click on the **QRS Model Server**.

- Click on the **ASAC Model Wizard**.

- From the list of models, click on the **ASAC Air Carrier Investment Model-Cargo**.

Screen 1 displays.

Figure A-2. Screen 1

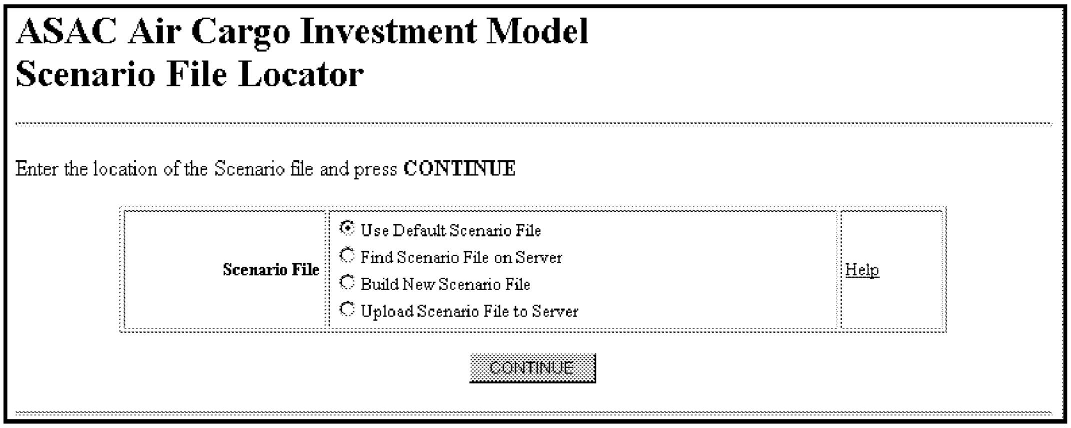


Choose an option from the drop-down list beside the **Air Cargo Model or Utility.** The first choice on the drop-down list is to run the model. If that choice is made, the next screen sets up the scenario file.

Note: Assign yourself a session name in the **Session Name** field.

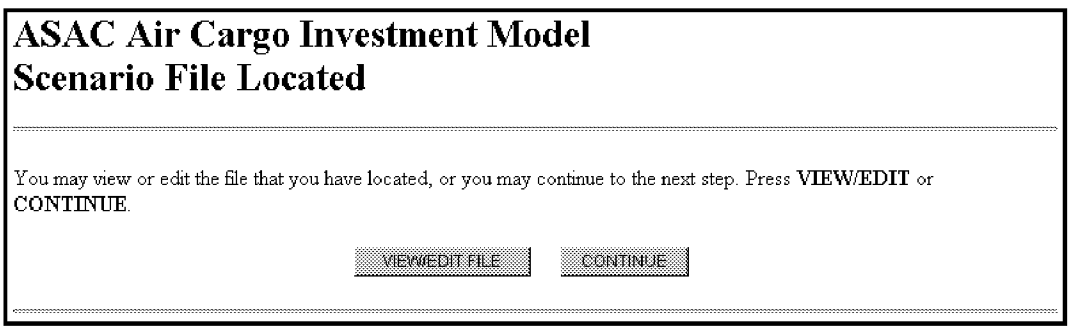
Click on the **[CONTINUE]** button. Screen 2 displays.

Figure A-3. Screen 2



To build a new scenario file, click on that option then click on the **[CONTINUE]** button. Screen 3 displays.

Figure A-4. Screen 3



Click on the **[VIEW/EDIT FILE]** button to edit or change particular parameter values or click on **[CONTINUE]** to bypass editing.

Seven different data sets define a scenario file. Editing any set of these files allows the user to generate specific scenarios for evaluation. If you select **[VIEW/EDIT FILE]**, a selection of these seven sets for editing is accomplished in the View/Edit mode. Each selected set then is available for on-line editing, with the currently implemented value shown. An automatic error-checking algorithm ensures that each value is within realistic bounds. Those bounds are shown in Table A-1. This checking process is shown in Screens 4 to 11. Follow the steps directed at the top of each screen.

Table A-1. Upper and Lower Bounds of Variable Parameters

Parameter	Lower	Upper
Real GDP growth rate	-0.1	0.1
Real cargo yield	-0.1	0.1
Percentage of cargo aircraft demand met by converted passenger	0.0	1.0
U.S. market share of demand for new cargo aircraft	0.0	1.0

Figure A-5. Screen 4

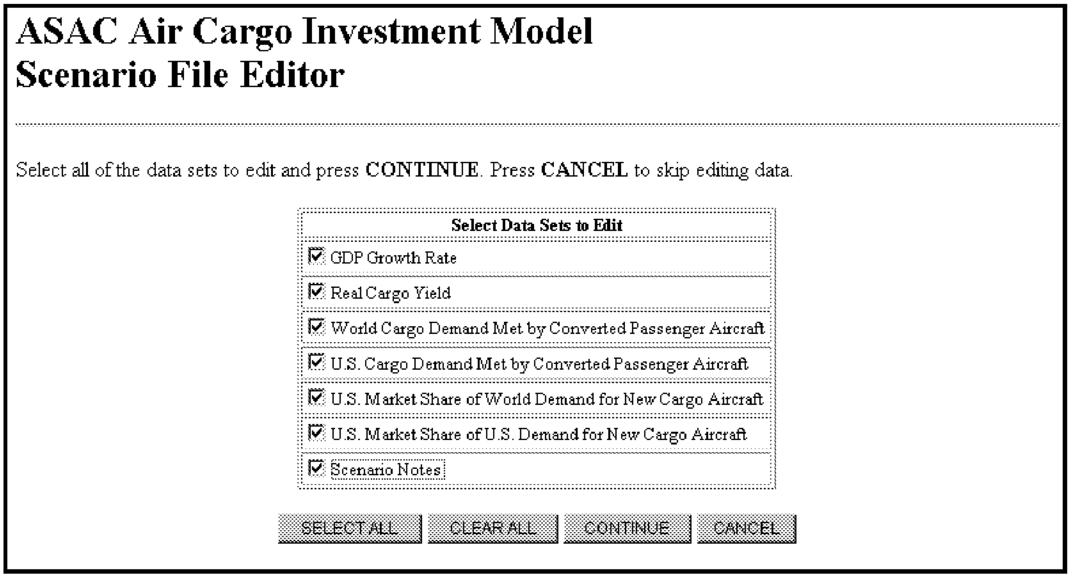


Figure A-6. Screen 5

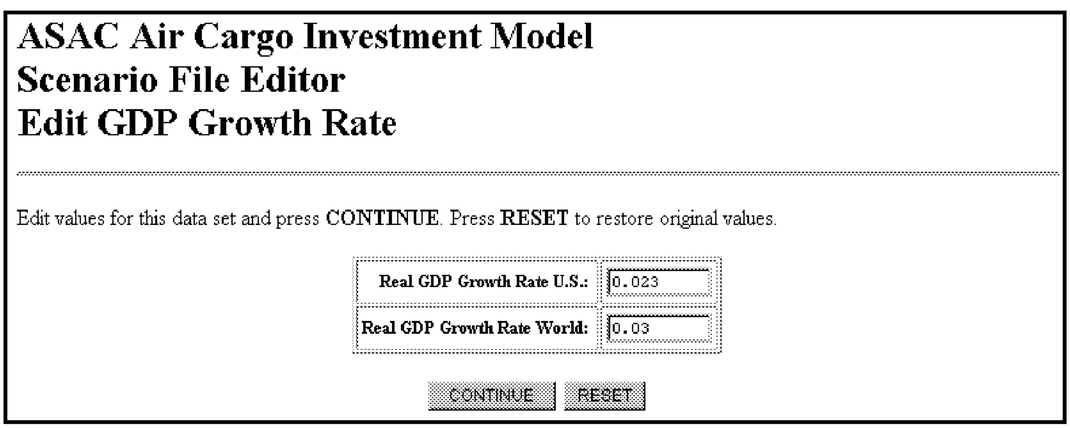


Figure A-7. Screen 6

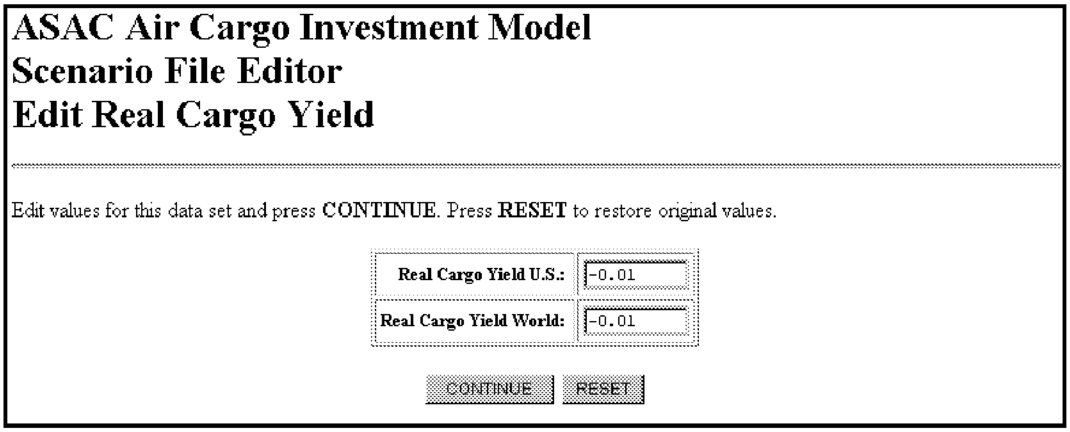


Figure A-8. Screen 7

Figure A-9. Screen 8

ASAC Air Cargo Investment Model
Scenario File Editor
Edit U.S. Cargo Demand Met by Converted Passenger Aircraft

Edit values for this data set and press **CONTINUE**. Press **RESET** to restore original values.

% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 1997:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 1998:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 1999:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 2000:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 2001:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 2002:	0.7
% of Cargo Aircraft Demand Met by Converted Passenger Aircraft U.S. 2003:	0.7

Figure A-10. Screen 9

ASAC Air Cargo Investment Model
Scenario File Editor
Edit U.S. Market Share of World Demand for New Cargo Aircraft

Edit values for this data set and press **CONTINUE**. Press **RESET** to restore original values.

U.S. Market Share of World Demand for New Cargo Aircraft 1997:	0.65
U.S. Market Share of World Demand for New Cargo Aircraft 1998:	0.65
U.S. Market Share of World Demand for New Cargo Aircraft 1999:	0.65
U.S. Market Share of World Demand for New Cargo Aircraft 2000:	0.65
U.S. Market Share of World Demand for New Cargo Aircraft 2001:	0.65
U.S. Market Share of World Demand for New Cargo Aircraft 2002:	0.66

Figure A-11. Screen 10

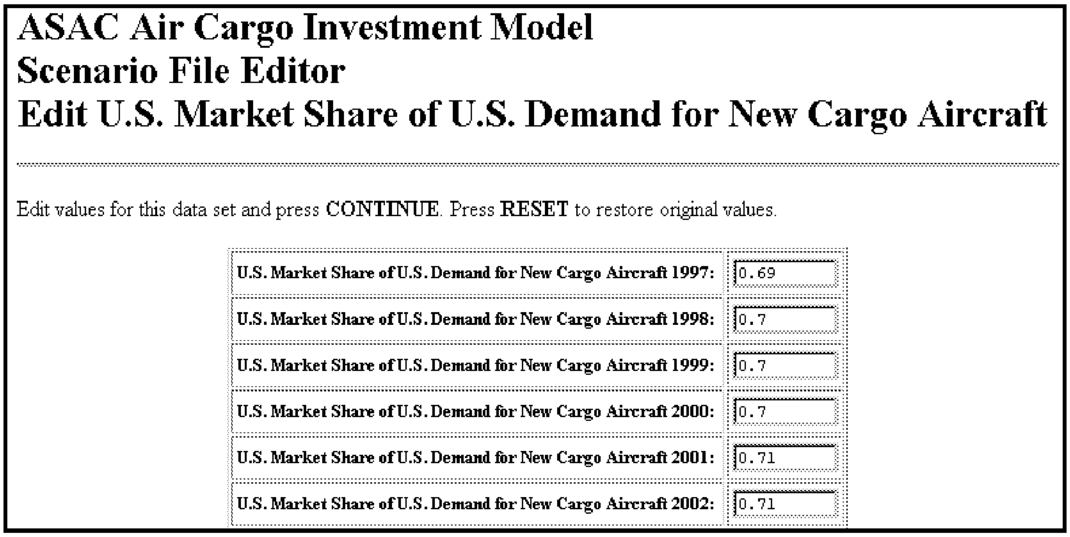
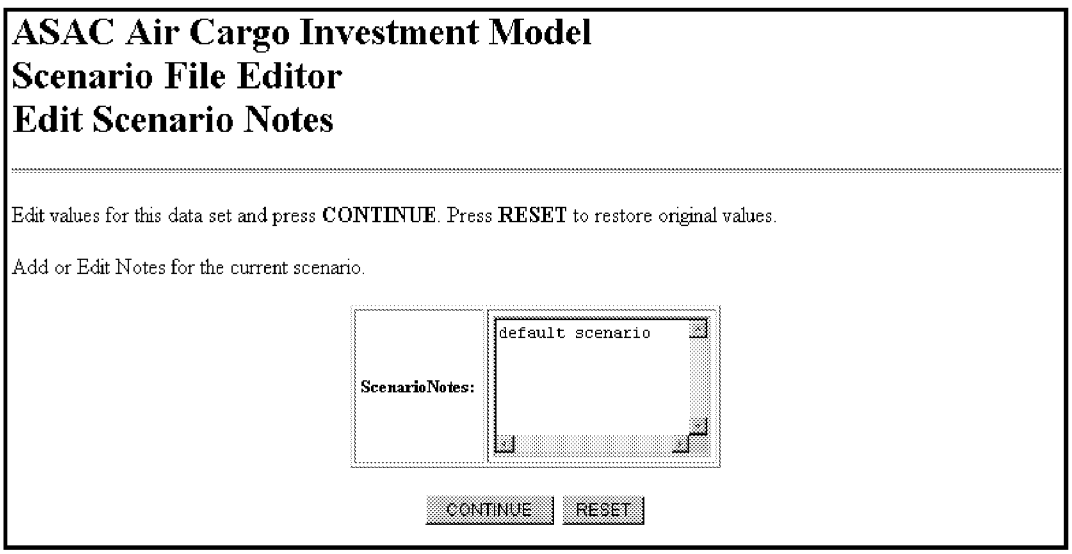


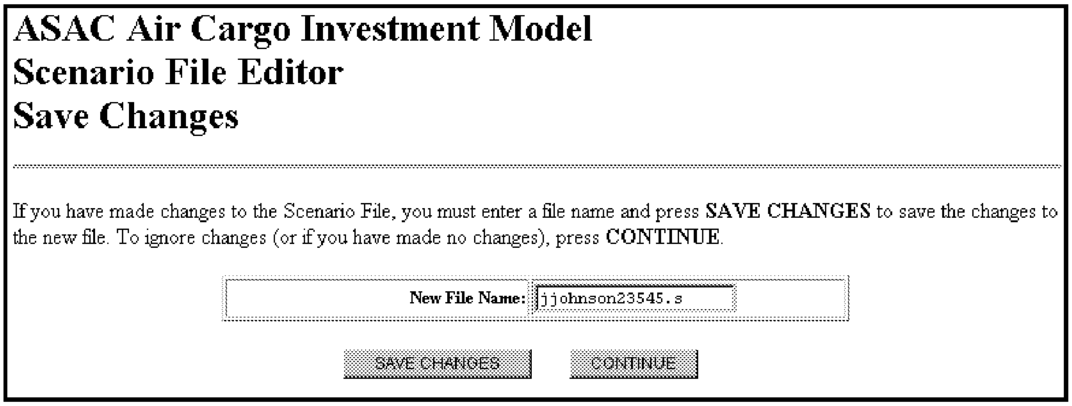
Figure A-12. Screen 11



Once all field updates have been made, click on the **[CONTINUE]** button on Screen 11.

The ASAC Air Cargo Investment Model Scenario File Editor Save Changes screen displays (Screen 12).

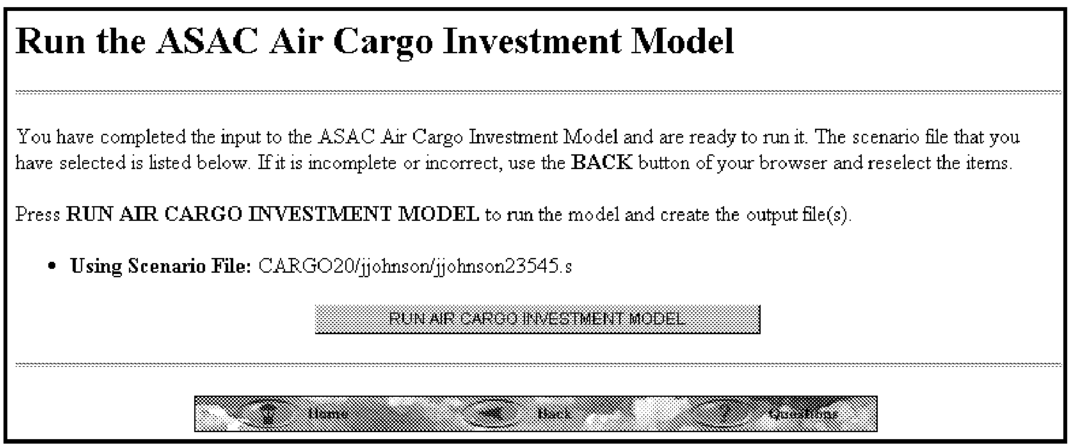
Figure A-13. Screen 12



Click on the **[SAVE CHANGES]** button to save the file scenario.

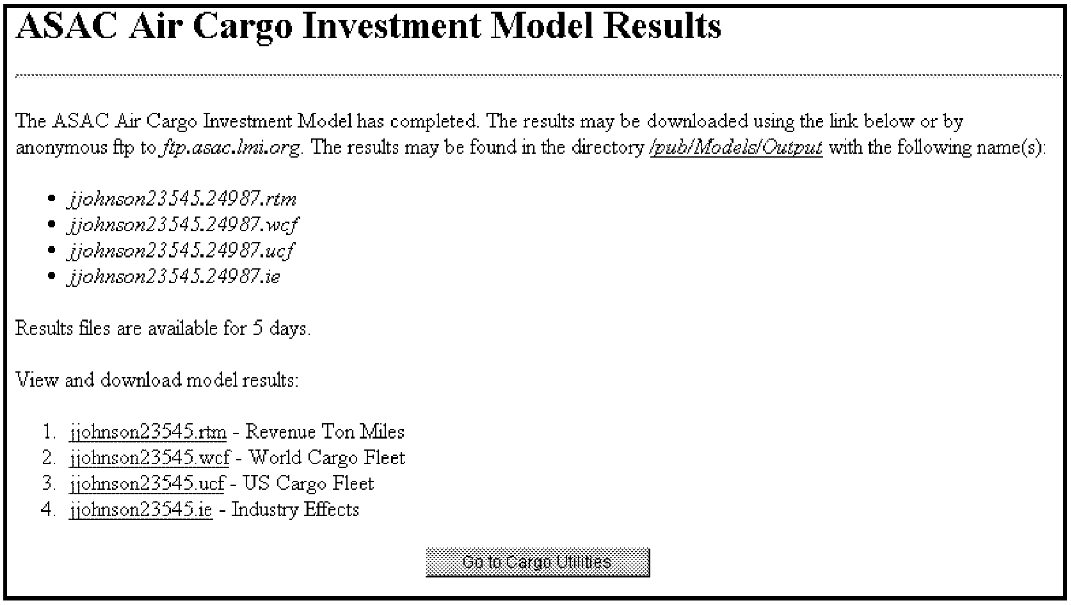
The Run the ASAC Air Cargo Investment Model screen displays.

Figure A-14. Screen 13



Click on the **[RUN AIR CARGO INVESTMENT MODEL]** button. Screen 14 displays, which lists the files containing the results of the particular scenario.

Figure A-15. Screen 14



Four results files are possible for each scenario. These are shown in Screen 14. The .rtm file contains the yearly total RTM estimates for both the U.S. and World regions. The .wcf file contains the yearly world cargo fleet data, including the total yearly additions to the cargo fleet, the yearly number of new cargo aircraft purchased, and the yearly number of new U.S.-made cargo aircraft purchased. The .ucf file contains the exact same information, but for the U.S. cargo fleet. The .ie file contains the yearly and summary industry effects data for both the world and U.S. regions; this includes the manufacturing work years, manufacturing industry value, and airline employment arising from the sales of new U.S.-made cargo aircraft.

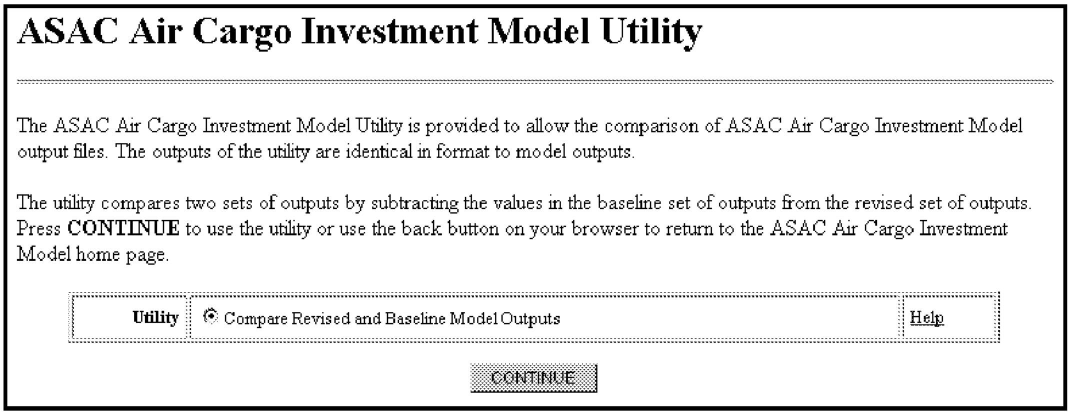
The user now has two options: (1) the compare utility, which calculates the difference between revised and baseline cases and can be accessed by clicking on the **[Go to Cargo Utilities]** button; or (2) another case can be set up and run by returning to he initial model setup step by pressing the **[Back]** button at the bottom of the screen.

ASAC ACIMC Utility

The air cargo utility model compares the results of any two scenarios and computes the difference. When one case is defined to be a baseline and another represents a technology insertion, then the difference is the effect of the technology insertion.

From the initial screen (Screen 1), select the utility. Screen 15 here has only one option: **Compare Revised and Baseline Model Outputs**. Click on the radio button.

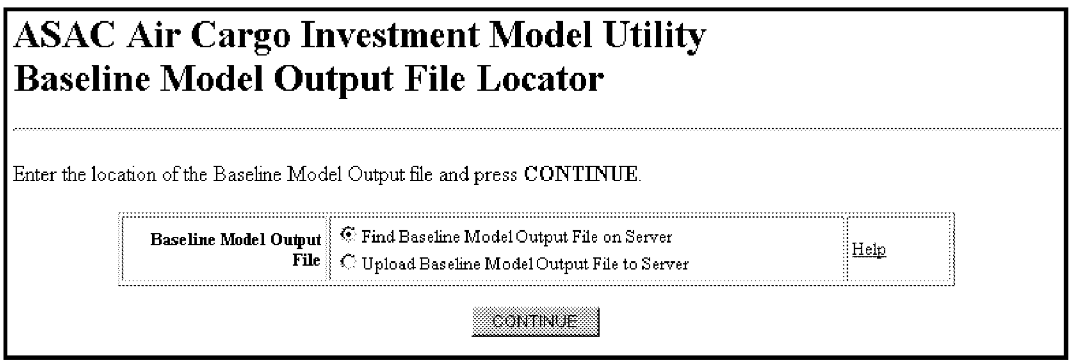
Figure A-16. Screen 15



Click on the **[CONTINUE]** button.

Screen 16 displays.

Figure A-17. Screen 16



The user is offered two options for the baseline model output file: **Find Baseline Model Output File on Server** or **Upload Baseline Model Output File to Server**. Once either of these options is completed, the same steps are rerun, except this time for the revised model. This process is shown in Screens 17 to 20.

If the *first* option is chosen, a list of available files displays (see Screen 17). If the *second* option is chosen, a screen for performing an http upload displays. Select the appropriate file and click on the **[CONTINUE]** button. Screen 18 displays.

Figure A-18. Screen 17

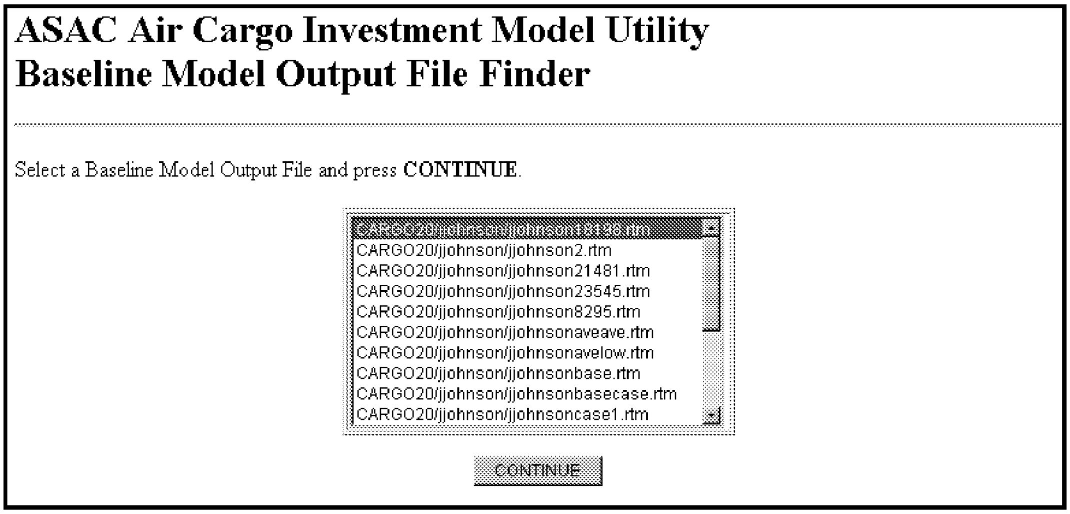
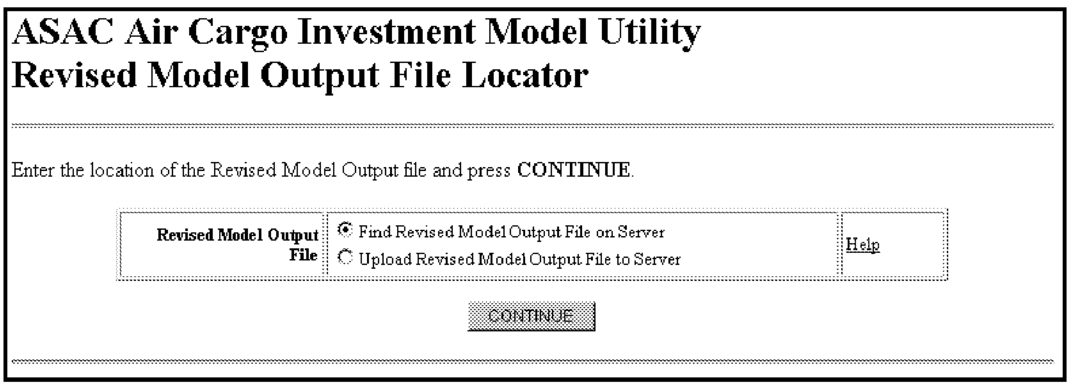


Figure A-19. Screen 18



Click on the desired radio button and then click on **[CONTINUE]**. Screen 19 displays.

Figure A-20. Screen 19

ASAC Air Cargo Investment Model Utility
Revised Model Output File Finder

Select a Revised Model Output File and press **CONTINUE**.

CARGO20/jjohnson/jjohnsonbasecase.rtm
CARGO20/jjohnson/jjohnsoncase1.rtm
CARGO20/jjohnson/jjohnsoncompare1.rtm
CARGO20/jjohnson/jjohnsonhighaverage.rtm
CARGO20/jjohnson/jjohnsonhighhigh.rtm
CARGO20/jjohnson/jjohnsonhighlow.rtm
CARGO20/jjohnson/jjohnsonlowave.rtm
CARGO20/jjohnson/jjohnsonlowhigh.rtm
CARGO20/jjohnson/jjohnsonlowlow.rtm
CARGO20/jjohnson/jjohnsonoct21.rtm

CONTINUE

From this screen a selection of the Revised Model Output File is made. Then click on **[CONTINUE]** and screen 20 displays.

Screen 20 displays the names of the baseline and revised models displays.

Figure A-21. Screen 20

Run ASAC Air Cargo Investment Model Utility

You have completed the input to the ASAC Air Cargo Investment Model Utility and are ready to run the utility. The files that you have selected are listed below. If any of them are incomplete or incorrect, use the **BACK** button of your browser and reselect the items.

- **Using Baseline Model Output:** CARGO20/jjohnson/jjohnsonbase.rtm
- **Using Revised Model Output:** CARGO20/jjohnson/jjohnsonhighhigh.rtm

Press **RUN AIR CARGO INVESTMENT MODEL UTILITY** to run the utility and create the output files.

RUN AIR CARGO INVESTMENT MODEL UTILITY

Click on the **[RUN AIR CARGO INVESTMENT MODEL UTILITY]** button and Screen 21 displays.

Figure A-22. Screen 21

ASAC Air Cargo Investment Model Utility Results

The ASAC Air Cargo Investment Model Utility has completed. The results may be downloaded using the link below or by anonymous ftp to *ftp.asac.lmi.org*. The results may be found in the directory */pub/Models/Output* with the following name(s):

- *jjohnson23545.25922.rtm*
- *jjohnson23545.25922.wcf*
- *jjohnson23545.25922.ucf*
- *jjohnson23545.25922.ie*

Results files are available for 5 days.

View and download model results:

1. jjohnson23545.rtm - Revenue Ton Miles
2. jjohnson23545.wcf - World Cargo Fleet
3. jjohnson23545.ucf - US Cargo Fleet
4. jjohnson23545.ie - Industry Effects

As in the ASAC ACIMC, the same four output files are available (on Screen 21): .rtm, .wcf, .ucf, and .ie, except here, the results are the yearly and summary data of the differences between the baseline and revised model outputs.

Parameter Updates

Six sets of parameters can be varied as part of specific analyses. These are GDP Growth Rate, Real Cargo Yield, World Cargo Demand Met by Converted Passenger Aircraft, U.S. Cargo Demand Met by Converted Passenger Aircraft, U.S. Market Share of World Demand for New Cargo Aircraft, and U.S. Market Share of U.S. Demand for New Cargo Aircraft. They also can be used to refine and redefine the baseline case.

Since the model is based on regression analysis, over time, the estimates may become "stale." That is, the estimated data will begin to diverge from the actual data. The preferred solution to this problem is to rerun the historical data and update the econometric parameters (the data elements shown in Table 1) that drive the model. After the analysis is done, the model would have to be "opened" and the parameters updated. This method is described in the next section.

This may not be possible at all times, so an alternative method can be used. Since the regression coefficients are elasticities, the value of the GDP can be used to produce an updated RTM estimate that is consistent with real or observed data. This scenario then can be defined as the baseline case; and all other scenarios can be evaluated relative to this one.

Similarly, the same updating or estimation correction process can be used on the following parameters: World Cargo Demand Met by Converted Passenger Aircraft, U.S. Cargo Demand Met by Converted Passenger Aircraft, U.S. Market Share of World Demand for New Cargo Aircraft, and U.S. Market Share of U.S. Demand for New Cargo Aircraft. These may deliver a higher fidelity estimate because each of these parameters can be changed on a yearly basis.

MODEL UPDATES

The following set of parameters are expected to change over time. At some point in the future, data analysis will need to be performed to update these parameters. All of these parameters are found in the "cargo constants file." They are

- World LN GDP,
- World LN cargo yield,
- U.S. LN GDP,
- U.S. LN cargo yield,
- World LN RTM,
- World LN cargo RTM,
- U.S. LN RTM,
- World RTM coefficient 1,
- World RTM coefficient 2,
- Manufacturing value per $1 million aircraft,
- Manufacturing work years per $1 million aircraft,
- Weighted cost of a new cargo aircraft, and
- Air carrier industry employment per aircraft.

The last set of constants enables changes in the starting and ending years of the analysis. They all are found in the acimc_constants.h file. Changing any of these also requires recompiling the program file. These parameters are

- Number of years of analysis,
- Number of fleets calculated,
- Starting size of the U.S. cargo fleet,
- Starting size of U.S. RTMs,

- Starting value of the U.S. yearly delta in cargo aircraft,
- Starting size of the world cargo fleet,
- Starting size of world RTMs, and
- Starting value of the world yearly delta in cargo aircraft.

Appendix B
Abbreviations

ACIM	Air Carrier Investment Model
ACIMC	Air Carrier Investment Model-Cargo
ASAC	Aviation Systems Analysis Capability
GDP	Gross Domestic Product
ICAO	International Civil Aviation Organization
LMI	Logistics Management Institute
NASA	National Aeronautics and Space Administration
OECD	Organization of Economic Cooperation and Development
RTK	revenue tonne kilometer
RTM	revenue ton mile
WWW	World Wide Web